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Life-history review of *Oobius zahaikevitshi* Trjapitzin, 1963 (Hymenoptera: Encyrtidae), an egg parasitoid of jewel beetles (Coleoptera: Buprestidae)

Обзор образа жизни *Oobius zahaikevitshi* Trjapitzin, 1963 (Hymenoptera: Encyrtidae), паразитоида яиц златок (Coleoptera: Buprestidae)

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КЛЮЧЕВЫЕ СЛОВА: Hymenoptera, Encyrtidae, Coleoptera, Buprestidae, *Oobius zahaikevitshi*, *Agrilus suvorovi*, образ жизни, Украина.

ABSTRACT. The oviposition and immature development were studied for *Oobius zahaikevitshi* Trjapitzin, 1963 (Hymenoptera, Encyrtidae), an egg parasitoid of a jewel beetle *Agrilus suvorovi* Obenberger, 1935 on aspen trees. The female first penetrates the protective shield of host eggs with its ovipositor. Then she lays an egg bearing a long aeroscopic plate with widened bulbus at its end. The posterior end of the newly hatched larva is attached to the egg chorion, which is connected by the aeroscopic plate to the host egg. The second-instar larva possesses a distinct tracheal system connected to the aeroscopic plate. The final-instar larva is disconnected from the aeroscopic plate and bears a row of lateral spiracles. The freshly molted pupa of *O. zahaikevitshi* is pale, but darkens later; the parasitoid overwinters at the pupal stage.

РЕЗЮМЕ. Изучен процесс яйцекладки и преимагинального развития *Oobius zahaikevitshi* Trjapitzin, 1963 (Hymenoptera, Encyrtidae), паразита яиц златки *Agrilus suvorovi* Obenberger, 1935 на осине. Самка сначала прокалывает защитный покров яиц хозяина с помощью яйцеклада. Затем она откладывает яйцо, имеющее длинную аэроскопическую пластинку, с расширенным бульбусом на конце. Задний конец только что вышедшей личинки прикреплен к хориону яйца, который связан с яйцом хозяина с помощью аэроскопической пластинки. Личинка 2-го возраста имеет выраженную трахейную систему, соединенную с аэроскопической пластинкой. Личинка последнего возраста отсоединена от аэроскопической пластинки и несет ряд латеральных дыхалец. Только что перелинявшая куколка *O. zahaikevitshi* имеет бледные покровы, однако позже темнеет; паразитоид зимует на стадии куколки.

Introduction

Xylophagous jewel beetles (Buprestidae) are important pests of wood around the world; some of them (e.g. the emerald ash borer (EAB), *Agrilus planipennis* Fairmaire, 1888), cause significant damage to economically valuable trees [Haack et al., 2002]. Utilization of native parasitoids is a successful approach to control the invasive jewel beetles. For example, the exotic EAB (originating from South-East Asia) is successfully controlled by its native parasitoids *Spathius agrili* Yang, 2005 (Braconidae), *Tetrastichus planipennisi* Yang, 2006 (Eulophidae) and *Oobius agrili* Zhang et Huang, 2005 (Encyrtidae) in North America [Duan et al., 2012].

The genus *Oobius* was established by V.A. Trjapitzin [1963] for the two species, *O. rudnevi* (Nowicki, 1928) (the type species) and *O. zahaikevitshi* Trjapitzin, 1963, both the parasitoids of eggs of xylophagous beetles. Now the genus includes 42 described species in the World fauna [Noyes, 2012]. The genus belongs to the tribe Oobiina and is characterized by the small (about 1.0 mm in length), compact, and mainly black body (Fig. 1c–f), rather wide frontovertex, ocelli situated in an obtuse triangle, 6-segmented antennal funicle and large 3-segmented clava of female (Fig. 3a), filiform male flagellum (Fig. 3b), 3-toothed mandibles, absence of notauli, transparent wings with a broad (1.5–2.0 times as long as wide) marginal vein and postmarginal vein, which is just a little longer than the

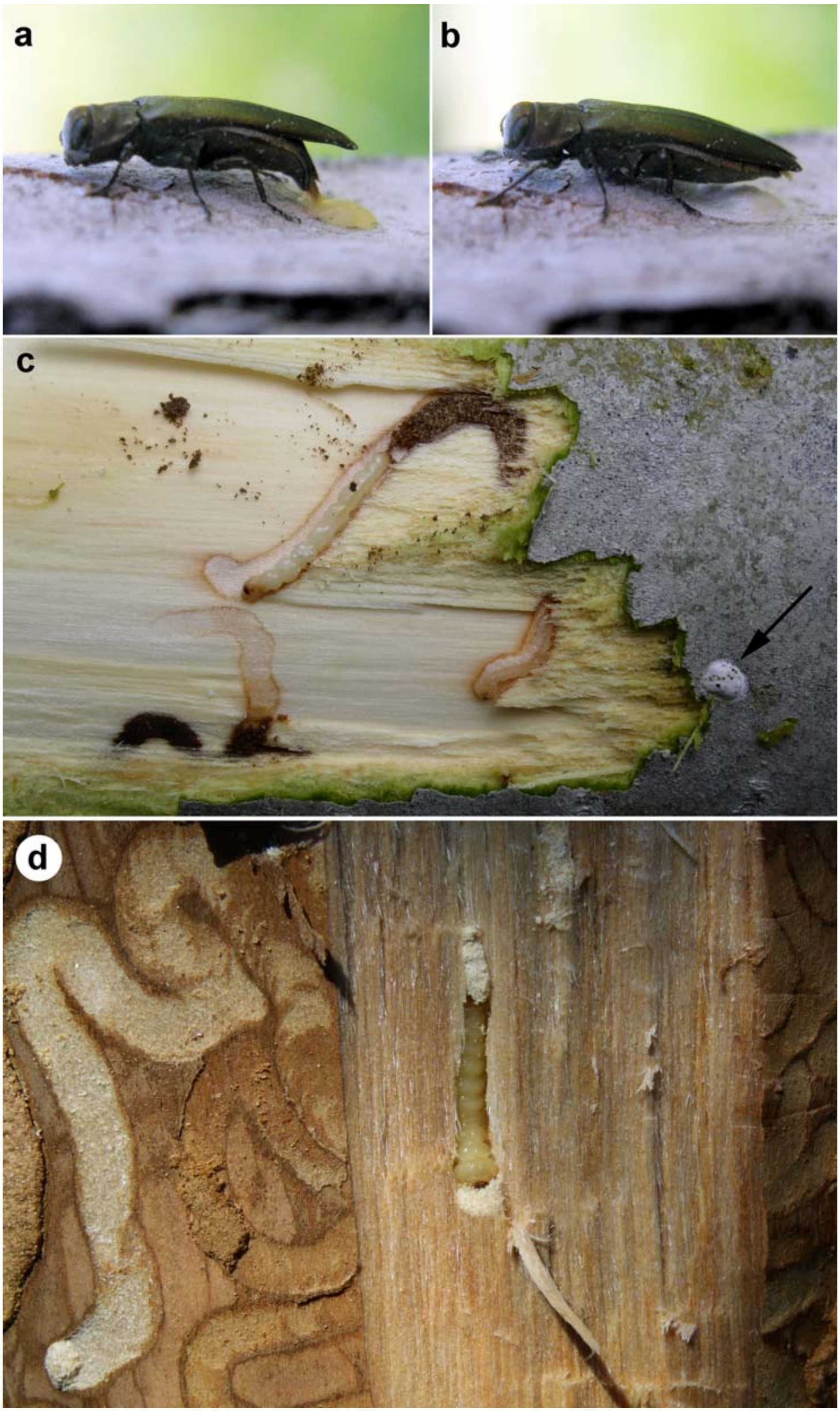


Fig. 1. Oviposition of *Agrilus suvorovi*: a — egg-laying female, b — female remaining above the egg set covered with hardened secretion; c — beetle galleries with young larvae inside (egg set is arrowed); d — prepupa in aspen wood.

Рис. 1. Откладка яиц *Agrilus suvorovi*: a — самка в момент яйцекладки, b — самка, находящаяся над кладкой, покрытой затвердевшим секретом; c — ходы жука с молодыми личинками внутри (яйцекладка обозначена стрелкой); d — предкуколка в древесине осины.

marginal; linea calva of forewing with filum spinosum (Fig. 3c); VII sternite almost reaching apex of gaster. Males of *Oobius* are characterized by filiform antennae having funicular segments longer than wide as well as the solid clava.

O. zahaikevitshi may be distinguished from other species of the genus by combination of the following characters: female pedicel as long as three first funicle segments combined (first segment brown, 5th segment subquadrate and larger than preceding segments, Fig. 3a); outer mandibular tooth is rather large, distinctly separated from the rest of teeth; third joint of maxillary palpus is more than twice longer than the second. This species was recorded as an egg parasitoid of Buprestidae [Trjapitzin, Volkovitsh, 2011; Noyes, 2012], however, no data on its immature stages were available.

This paper is a first record on biology of *O. zahaikevitshi*, but it also appreciates a significant contribution of V.A. Trjapitzin to Chalcidoidea research in general, and to that of the family Encyrtidae in particular.

Materials and methods

The field observations were done in the nature reserve “Bobrovnya” on the Dnieper River (Ukraine, Kiev, Muromets Island), 50°31′12″N, 30°32′53″E during May–June 2011. Collected females of the parasitoid as well as egg sets of the host beetles were taken to the laboratory for further observations. The parasitized hosts were dissected either immediately or after daily intervals when oviposition was detected. Field photo recording was done using Canon PowerShot A-630 camera. Light microscopy observations were carried out using the Olympus system microscope CX-41 connected to Olympus digital camera C-4040ZOOM, under Olympus DP-Soft software (Version 3.2).

Material studied: 4 ♀♀, Ukraine, Kiev, Muromets Is. on the Dnieper River, the nature reserve “Bobrovnya”, 50°31′12″N 30°32′53″E, coll. 9.06.2011 (Gumovsky & Prokhorov); 6 ♀♀, 5 ♂♂, ibid., reared 10–12.06.2011 (Prokhorov) (Schmalhausen Institute of Zoology of National Academy of Sciences of Ukraine, Kiev).

Results

The host, *Agrilus suvorovi* Obenberger, 1935

In Ukraine, adult beetles occur from late May to early July, being the most numerous in June; they generally attack the young aspen and poplar trees [Prokhorov, 2010] (Fig. 2a, b). Sometimes the eggs are also laid on branches of older trees, or even logged or fallen ones.

A. suvorovi is a monovoltinous species. Oviposition takes place in early or mid June. Females lay 15–17 eggs [Bílý, 2002] on the bark of the host tree (Fig. 1a) and coat them with a quickly hardening secretion, which forms a rounded protective shield (Fig. 1b). The eggs develop for about 10 days. Newly hatched larvae penetrate the bark and bore into phloem. The young larvae feed in there forming serpentine galleries (Fig. 1c, d), which are often inosculated with each other. The mature larva shortly penetrates into the sapwood (about 5.0–10.0 mm deep), where it prepares a pupal chamber. The latter has a slightly curved irregular oval shape. The prepupa (Fig. 1d) overwinters, and pupation occurs in April and May.

The parasitoid, *Oobius zahaikevitshi*

Life history

The females of *O. zahaikevitshi* can be found in nature in mid May, what coincides with the oviposition time of *A. suvorovi*. The female walks on the laid host eggs, drums their surface with her antennae and eventually bends the gaster and starts ovipositing. Drilling of the host egg lasts long, up to 10–15 minutes, likely due to the necessity to penetrate the protective shield, formed by the hardened secretion of the female host. The freshly parasitized egg generally bears some drops of liquid on its surface as evident markings of the parasitoid oviposition. Larval development lasts for about seven days, and pupae are found in the host eggs at least in about two weeks after oviposition. *O. zahaikevitshi* overwinters at the pupal stage.

The parasitoid females are attracted by the egg sets of *A. suvorovi* in nature. In our laboratory experiments, the females of *O. zahaikevitshi* were also attracted by the egg sets of another jewel beetle, *Agrilus ribesi* Schaefer, 1946. Despite the females reacted to the eggs of the beetle by antennal drumming and ovipositor probing, no eggs were laid.

Egg

The ovarian egg (Fig. 4a, b) is about 0.2 mm long and 0.1 mm wide, with distinct (about 0.25 mm long) petiole (= aeroscopic plate) with a bulbus (0.1 mm long, 0.05 mm wide) at its end. The aeroscopic plate bears a distinct reticulation in its basal half.

First-instar larva

The first-instar larva (Fig. 4c, d) stays attached to the petiole, so that its posterior segments are covered by the egg chorion. The larva is milky in color (Fig. 4d), distinctly segmented, but the precise number of segments (as well as spiracles) is hardly distinguishable under light microscopy. The surface of the segments is covered by short swellings and pustulae (Fig. 5a). The head capsule is small, flattened, with somewhat elongate mouthparts (Fig. 5a).

Second-instar larva

Second-instar larva was identified through the molt of the first-instar one (Fig. 5b). It is distinctly 13-segmented and also stays attached to the aeroscopic plate (Fig. 5b); its three terminal segments covered by the egg chorion that continues to the petiole of the aeroscopic plate. This larva possesses the distinct tracheal system, connected to the aeroscopic plate by two tracheae. Larval mouthparts are also elongate, but their details are hardly discernible.

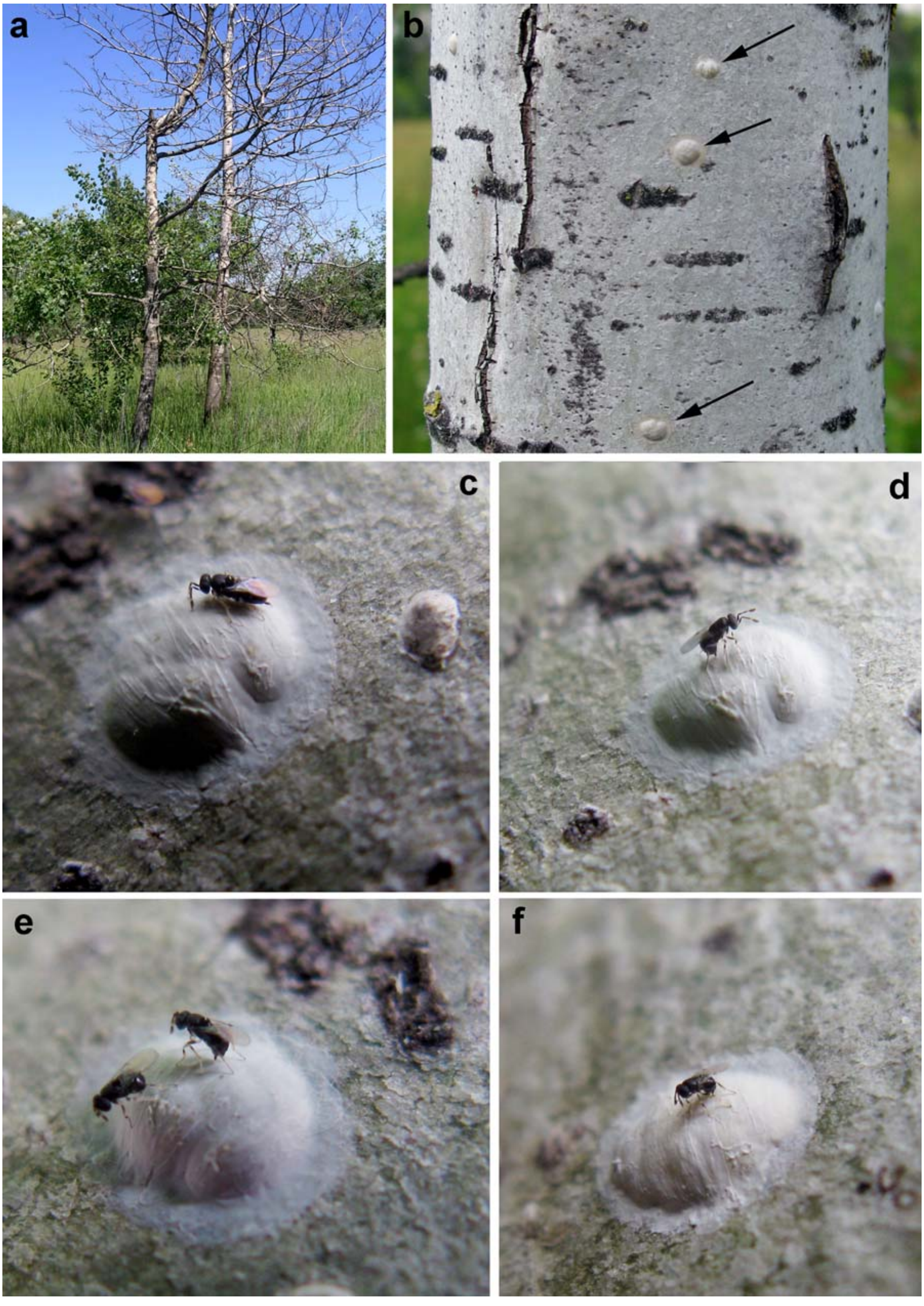


Fig. 2: a — aspen trees damaged by *Agrilus suvorovi*; b — egg sets of *A. suvorovi* at aspen bark; c–f — oviposition of *Oobius zahaikevitshi*.

Рис. 2: a — деревья осины, поврежденные *Agrilus suvorovi*; b — яйцекладки *A. suvorovi* на коре осины; c–f — откладка яиц *Oobius zahaikevitshi*.

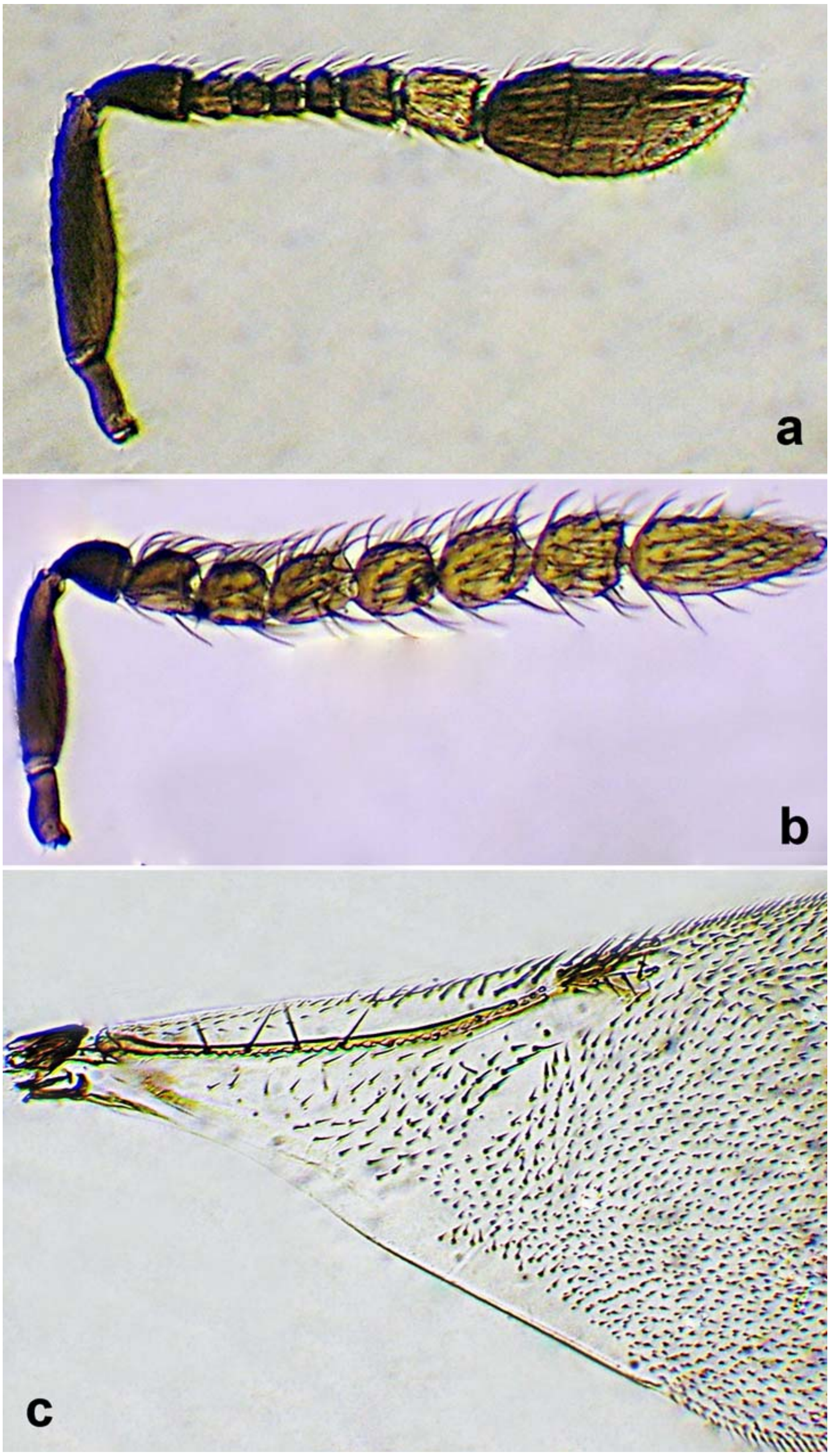


Fig. 3. Morphological features of *Oobius zahaikevitshi*: a — female antenna; b — male antenna; c — female, part of fore wing.
Рис. 3. Морфологические особенности *Oobius zahaikevitshi*: a — усик самки; b — усик самца; c — часть крыла самки.

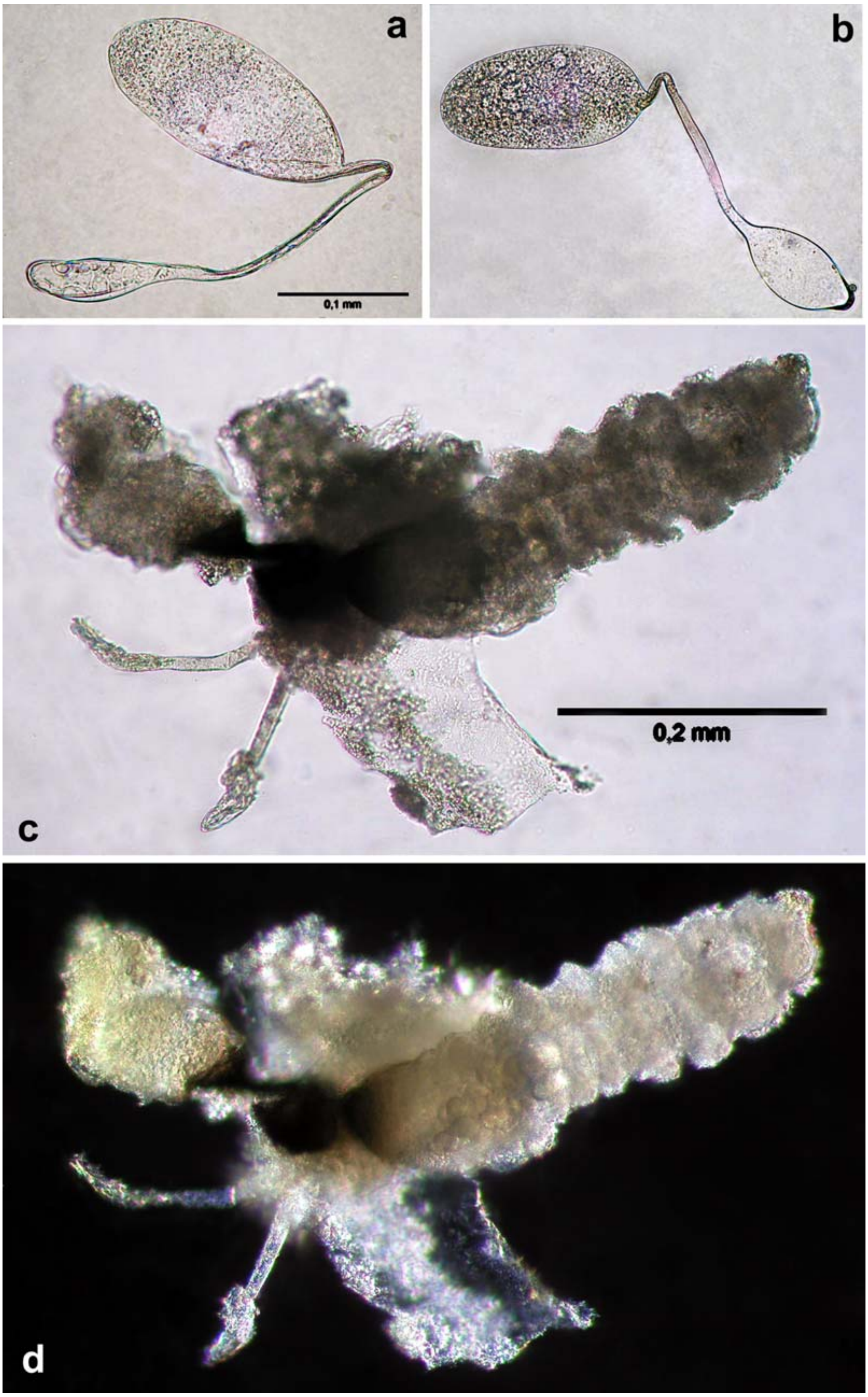


Fig. 4. Immature stages of *Oobius zahaikevitshi*: a, b — ovarian eggs; c, d — 1st-instar larva isolated from host egg.

Рис. 4. Преимагинальные фазы развития *Oobius zahaikevitshi*: a, b — яйца, выделенные из яичника; c, d — личинка 1-го возраста, извлеченная из яйца хозяина.

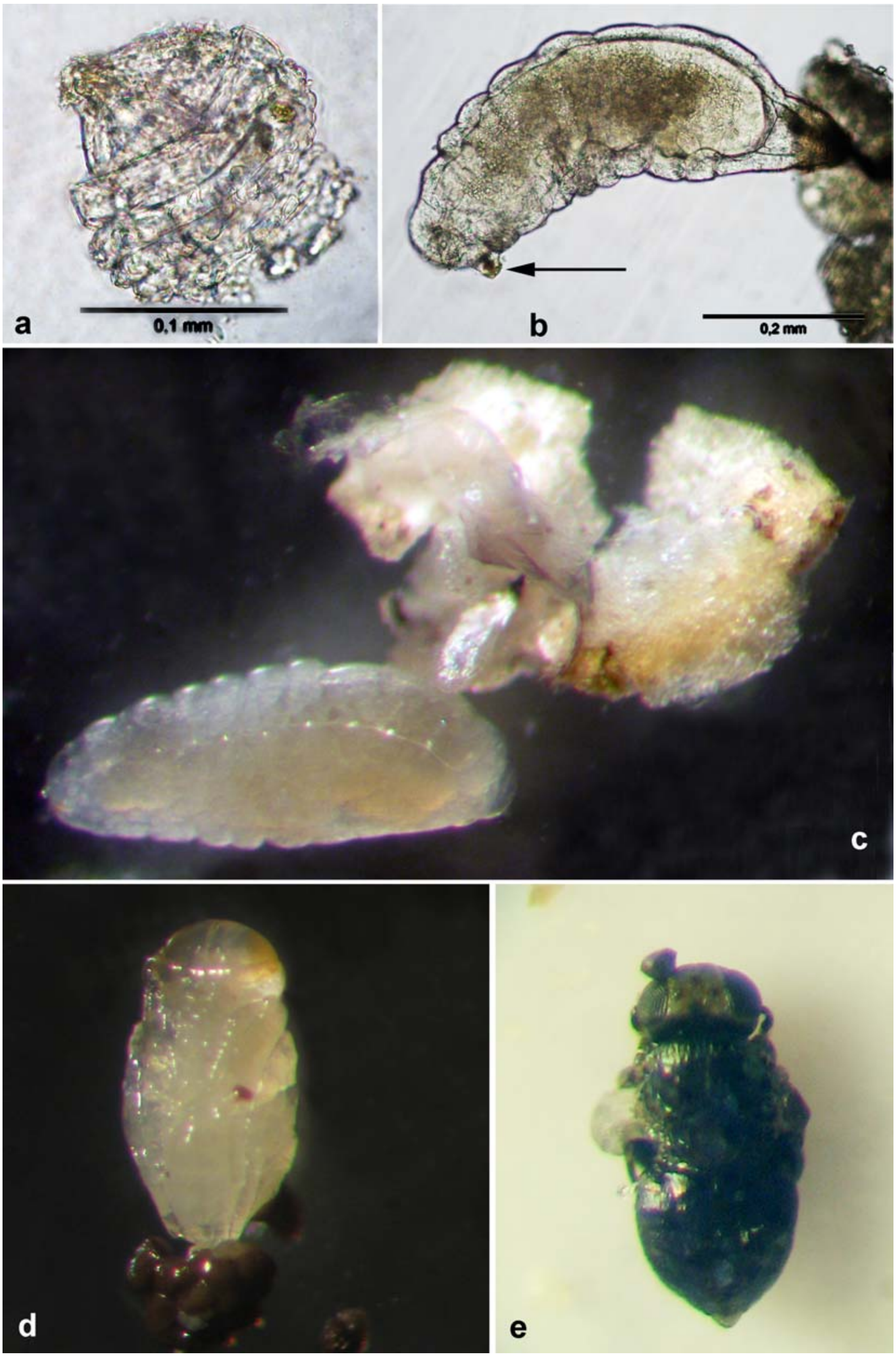


Fig. 5. Immature stages of *Oobius zahaikevitshi*: a — head of 1st-instar larva; b — molt into 2nd-instar larva (head capsule arrowed); c — final-instar larva; d, e — pupa, freshly molted (d), overwintering (e).

Fig. 5. Преимагинальные фазы развития *Oobius zahaikevitshi*: a — голова личинки 1-го возраста; b — линька личинки 1-го возраста на 2-й возраст (головная капсула личинки первого возраста обозначена стрелкой); c – личинка последнего возраста; d, e — куколка, вскоре после окукливания (d), готовая к зимовке (e).

Final-instar larva

Final-instar larva (Fig. 5c) is characterized by the presence of distinct lateral spiracles along the body side. The larva is disconnected from the egg chorion. It floats free within the egg contents when freshly molted; then it quickly consumes the rest of the egg and pupates.

Pupa

The pupa is exarate, with distinct structural definition of the head and abdomen, legs, mouthparts and antennae (Fig. 5d, e). The freshly molted pupa is pale to transparent, with a mass of meconium attached to its caudal end (Fig. 5d). In about two days, the pupa grows dark (Fig. 5e).

Discussion

The Encyrtidae is a family of the Chalcidoidea with the most diverse strategies of immature development [Trjapitzin, 1972, 1989]. This is the only family of chalcid wasps, in which some species are characterized by a remarkable developmental phenomenon called "polyembryony", when a single laid egg multiplies clonally and then produces large number of identical embryos. The eggs and larvae of other encyrtids have a number of chararacteristic structures, e.g. various respiratory appendages (for example, the aeroscopic plate). Trjapitzin [1972, 1989] summarized the data on immature development of encyrtids and proposed a subdivision into 8 groups. *Oobius zahaikevitshi* belongs to the encyrtids of the "Group I" proposed by Trjapitzin [1989]. This group is characterized by the eggs and larvae of "encyrtiform" [Clausen, 1940] or "banded" [Maple, 1947] type. These eggs are characterized by the distinct aeroscopic plate, which later becomes a respiratory device for the hatched larvae. The development described above fits completely the description of the "Group I". It is remarkable that the mouthparts of the larvae are rather tiny, poorly sclerotized and hardly discernible in both first and second instars.

O. zahaikevitshi has been recorded as an egg parasitoid of a wide range of *Agrilus* jewel beetles: i.e., unidentified *Agrilus* beetles [Trjapitzin, 1978; Viggiani, 1967], *A. cuprescens* (Ménétriés, 1832), *A. lopatini* Alexeev, 1964, *A. roscidus* Kiesenwetter, 1857, *A. shamyl* Obenberger, 1922 [Trjapitzin, 1989; Japoshvili, 2000], *A. olivicolor* Kiesenwetter, 1857 [Corte et al., 2009] and *A. viridis* Linnaeus, 1758 [Trjapitzin, Zagaikevich, 1971; Makhmadzieev, 1977; Trjapitzin, 1978; Trjapitzin, 1989; Japoshvili, 2000; Trjapitzin, Volkovitsh, 2011]. This is the first record of parasitism of this species in eggs of *A. suvorovi* on aspen trees. Since the females of *O. zahaikevitshi* were attracted by the eggs of the non-host jewel beetle, *Agrilus ribesi*, this species presumably attacks substantially wider host range in absence of the preferred host.

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